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PHYSICAL PROCESSES STUDY OF GOLDSMITH INLET, NEW YORK

Michael J. Morgan[1], Nicholas C. Kraus[2]

1. U.S. Army Engineer District, New York, 26 Federal Plaza, New York, NY 10278. Michael.J.Morgan@usace.army.mil.
2. U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, USA. Nicholas.C.Kraus@erdc.usace.army.mil.

Abstract: Goldsmith Inlet is a small semi-natural and non-navigable inlet located on the northeast shore of Long Island, NY, and it connects Goldsmith Pond to Long Island Sound. The coast is gravelly, waves relatively small because of limited fetch, and tide range relatively large at 2 m as compared to the south shore of Long Island. The inlet has been in existence since at least the 1700's, but is apparently prone to closure in recent times. Field data collection, GIS analysis of morphology, and numerical modeling of the inlet current were performed. The inlet is found to be highly flood dominant, with two natural sills restricting ebb flow. As a result, gravel remains at the inlet mouth, with the flood shoal composed of fine sand. No ebb shoal is found, probably a result of the limited ebb-tidal discharge. It is concluded that an easterly orientation promotes channel stability and is to be preferred to re-alignment of the inlet to run straight out to Long Island Sound.

INTRODUCTION

Goldsmith Inlet (Fig.1 and Fig. 2) is a small, semi-natural inlet located on the northeast shore of Long Island, NY, and connects Goldsmith Pond to Long Island Sound (Leatherman et al. 1997). The inlet is not navigable, and it is protected on the up-drift side by a structure called a jetty that should be considered as a groin in retaining sand on its up-drift (west) side. Goldsmith Inlet is of interest in that it is a gravelly inlet, migrates down drift, has no ebb shoal, is strongly flood dominant, and is relatively stable. This paper abstracts information contained in a comprehensive study by Morgan et al. (2005).

In contrast to the south shore of Long Island, inlets on the north shore have received little study. Many are small and serve small and isolated water bodies. North shore inlets appear to be more stable in location than the south shore inlets. The sediment along the south shore consists predominantly of fine to medium sand, with a median grain size of 0.3 mm being typical. In contrast to the sandy beaches backed by dunes found along the south shore, high bluffs and a wide range in grain size characterize the north shore of Long Island. The tide range along the north shore is about double that of the south shore and the waves along the north shore are smaller and steeper. Longshore sediment transport is an order of magnitude less on the north shore as compared to the south shore.

This paper discusses coastal processes at Goldsmith Inlet. Field data collection conducted in Oct 2002, during a spring tide, included surveys of the adjacent nearshore, inlet, and Goldsmith Pond; measurements of water level in Long Island Sound and in the pond; short-term measurement of the current; and sediment sampling. Available aerial photographs were obtained, starting in 1938, and aerial photographs of the study area were taken on 15 Apr 2003 and 16 Apr 2004. A GIS analysis of inlet morphology and morphology change was conducted. A tidal inlet hydrodynamics model DYNLET (Amein and Kraus 1991) was established to calculate the inlet current and water level.

Fig. 1. Goldsmith Inlet, 16 Apr 2003

Goldsmith Inlet has been in existence since at least the 1700s. Historically, a strong tidal current at Goldsmith Inlet is indicated by the presence of a tidal mill on Goldsmith Pond from about 1840 to the early 1890s. The sediment on the neighboring beaches is coarse sand to gravel, and the sediment in the inlet is primarily gravel and cobble.

Goldsmith Inlet has a depth of 0.3-0.6 m, and inlet width ranges from about 3 to 30 m. The mean width is about 15 m (Fig. 2), and it is approximately 360 m long. Goldsmith Pond has a mean depth of 0.5 m and a surface area of approximately 88,000 sq m. The tide range in this area is about 2 m, and spring tide range is 2.3 m. The tidal prism of

Goldsmith Inlet and Goldsmith Pond is calculated to be 8.5 x 10^4 m^3, based on measured bay area and half the spring tide range.

Fig. 2. Goldsmith Inlet entrance with view of east beach, 28 Mar 2003

Construction of the jetty was completed in 1964. Since 1964, the jetty has gradually deteriorated. Degradation and complete impoundment of sediment on the jetty's west side have led to greater sediment intrusion. The inlet has been occasionally dredged as a source of sand and gravel for upland activities and to provide sediment for renourishment of Kenneys Road Beach, located east and down drift of the inlet. More recently, Goldsmith Inlet has been dredged on an emergency basis, when the inlet has experienced closure, with the dredged material placed on the adjacent down-drift beach. Since the bathymetric survey of Oct 2002, the mouth of Goldsmith Inlet migrated to the east. In the winter of 2003-2004, a west-oriented spit accreted at the inlet mouth, redirecting the mouth slightly toward the west. The presence of ice directly east of the inlet may have been partially responsible for buildup of this west-oriented spit as well as the redirecting of the inlet mouth to the west. The Town of Southold has discussed the future of Goldsmith Inlet and the Goldsmith Inlet jetty. Beyond the creation of a deeper channel, an option being considered is shortening of the jetty, which may mitigate erosion east of the jetty yet still preserve a portion of the beach fillet west of it.

DATA COLLECTION

A bathymetric survey of the offshore adjacent to Goldsmith Inlet was conducted by boat on 6-8 Oct 2002. Goldsmith Inlet and Pond, the beaches adjacent to the inlet, and the area from the shoreline to wading depth were surveyed with a total survey station and surveying rod. The survey of Goldsmith Inlet and Goldsmith Pond was conducted on 8 Oct 2002. A water level gauge was deployed from 19 Sep to 8 Oct 2002. Flood current velocity was measured in the inlet from 1323 to 1643 GMT, 8 Oct 2002 by means of a hand-held current meter mounted on a pole that was sunk into the bed. Sediment samples were also taken.

Bathymetry

The coast west of Goldsmith Inlet is characterized by a relatively uniform shoreline and a large number of glacial erratics. The shoreline east of Goldsmith Inlet is less uniform. The area offshore on both sides of Goldsmith Inlet has a steep gradient, with a slope of approximately 1:10 from the beach to a depth of approximately 6 m NAVD88. A depression that is oriented parallel to the shoreline is located from 200 to 600 m offshore, where the depth reaches 7 m NAVD88. The entrance to Goldsmith Inlet is narrow and shallow. Depths range between 0.3 and 1.3 m NAVD88, and a large in-channel bar formation in the center of the channel becomes exposed during low tide. The channel has been observed to contain running water at all times during numerous field visits. At the time of the 6-8 Oct 2002 survey, the channel was 4 m wide at the entrance to the Long Island Sound and expanded to 35 m at the entrance to Goldsmith Pond.

An interesting finding of the survey is that Goldsmith Inlet lacks an ebb shoal. To the west of the inlet, an elevated formation (shoal) is located 300 to 600 m offshore. Because of this distance, this formation is not considered a consequence of either the modern or the historic inlet. Although the maximum ebb-current velocity at Goldsmith Inlet exceeds 1 m/sec and is comparable to that at other inlets that have formed ebb-tidal shoals, the volume of water flow or discharge is evidently too small to construct an ebb shoal. Sediment transported by the ebb current to the mouth of Goldsmith Inlet is transported from the entrance by waves and the wave-induced longshore current. This conclusion implies that bypassing from west to east occurs around the jetty, onto the spit, and back to the shore on the east side along a bypassing bar.

In contrast to lack of an ebb shoal, Goldsmith Inlet possesses a well-developed flood shoal consisting of three lobes. The lobes are located on the east bank, center channel, and west bank, where Goldsmith Inlet enters Goldsmith Pond (Fig. 3). Because of the mild elevation relief in the pond, the east and west lobes of the flood shoal are exposed during low water. The west lobe of the flood shoal is located approximately 250 m into the inlet. Sediment entering the inlet during flood tide is inferred to have formed this feature. This attachment on the west bank may redirect the ebb and flood tidal current and decrease the flushing capacity of the inlet. Sediment also approaches the inlet entrance from the spit that forms adjacent to the jetty. The entrance channel tends to align to the east, a characteristic that has become more pronounced with growth of the attachment shoal and the build-up of sediment along the jetty.

Water level

A tide gauge was placed near the southern bank of Goldsmith Pond and secured to the pond bottom. Water level at Goldsmith Pond is plotted in Fig. 4, together with that in Long Island Sound measured at the nearby Mattituck Inlet jetty (a Federal inlet located 8.4 km west of Goldsmith Inlet). In Goldsmith Pond, the average water level of the record was 0.28 m above NAVD88. This means that the pond does not completely empty to mean sea level (MSL), because the water flow is retarded by a sill in the area of the flood shoal, as indicated in Fig. 6 and, to a lesser extent, by a sill in the inlet located near the shoreline.

Fig. 3. Goldsmith Pond flood shoal. 16 Apr 2003

The measured tidal range within Goldsmith Pond varied from 0.37 to 1 m NAVD88. The mean tidal range for the deployment was calculated to be 0.66 m, with a spring tidal range of approximately 0.9 m for the period of record. The reduction in tide at Goldsmith Pond is, therefore, about 1 m or half the tidal range in Long Island Sound. Fig. 4 plots water level at Mattituck Inlet and Goldsmith Inlet for 5–7 Oct 2002. Because the tidal wave travels from east to west in Long Island Sound, the phase of the tide at Goldsmith Inlet will slightly lead that outside of Mattituck Inlet.

The bottom of the mouth of Goldsmith Inlet is located approximately at the elevation of the NAVD88 datum, near the visually observed mean shoreline position. Therefore, flow into the inlet and pond can only occur when the water level in the Sound is above MSL. The relation between NAVD88 and MSL at the mouth of the inlet is not known with confidence. Flow into the inlet and pond can only occur if the water level in the Sound is above the NAVD88 or MSL datums, according to the modeling results. When high tide is reached in the Sound, high tide in the pond occurs about 29 min later (median lag) and is 0.8 m lower. In contrast, the median phase lag for the low waters is 195 min (3.24 hr).

The long-term average water level in Goldsmith Pond is expected to be constant. The time duration of the high water is much shorter than the duration of the low water about the mean water level. Because the same amount of water must enter on flood as leaves at ebb to maintain the average water level in the pond, but in a shorter time, the average of the inlet channel cross-sectional current velocity on flood must be much greater than on ebb. Such an inlet is called flood dominant, referring to the greater magnitude, but shorter duration of the flood tide.

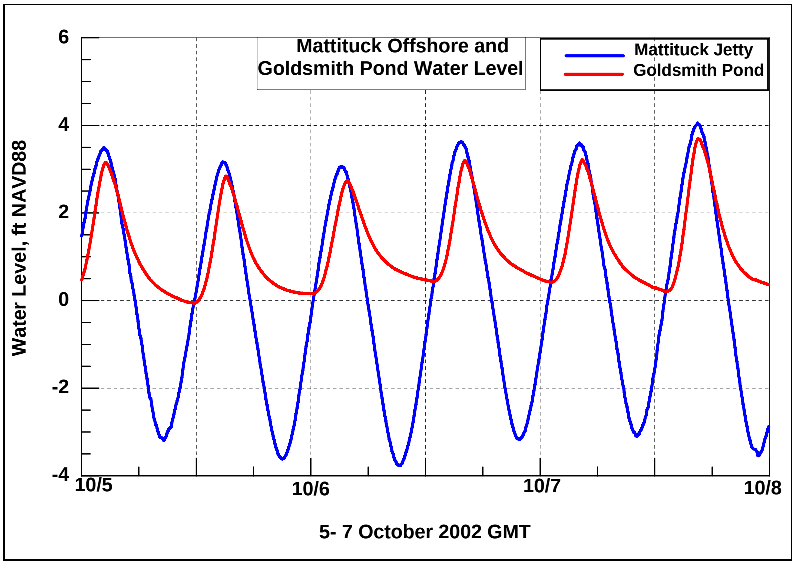

Fig. 4. Goldsmith Inlet water level, 5–7 Oct 2002

Current

The flood current velocity at mid depth and flood tide reached 1.3m/sec, after which the meter had to be removed because of concerns over the rising water level and strong current on. Corresponding to discussion of water level, there must be a strong asymmetry in current velocity at Goldsmith Inlet, with flood current being significantly stronger than ebb current. Sediment transport is proportional to a power of water velocity, typically the third power. Therefore, the flood-dominance will tend to transport sediment into Goldsmith Pond.

Sediment

Fourteen sediment grab samples were collected from Goldsmith Inlet on 8 Oct 2002, supplemented by 17 samples collected on 31 Jul 2003. The surficial sediment at the inlet entrance is predominantly composed of gravel (-6 to -2 ϕ). A transitional area is located around the shoal attached to the west bank where smaller gravel (-4 to -2 ϕ) dominates sand. The area of the inlet south of this region, which includes the flood shoal and the bottom of the pond is composed primarily of fine gravel and very coarse to coarse sand (-1 to 1 ϕ).

Figure 5 is a plan-view distribution of sediment grain size at Goldsmith Inlet. The plan view clearly shows fining of sediment with distance into the inlet and pond from the entrance. Current velocity magnitude plays a major role in determining the distribution of grain size within an inlet, resulting in a graded deposit and sorting within the channel. The greater velocity magnitude at the inlet mouth entrains and transports increasingly larger grain sizes. As the current velocity magnitude decreases, the larger grain size fractions are deposited, whereas finer sediments are transported further into the inlet.

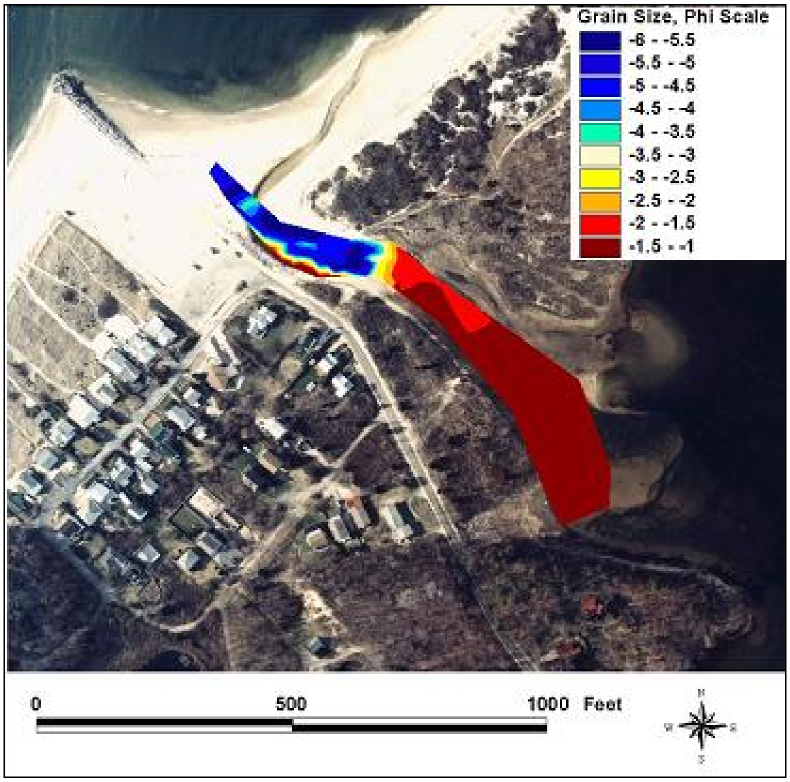

Fig. 5 Goldsmith Inlet median grain size distribution of surface samples

CALCULATION OF CURRENT

Water-surface elevation and current velocity at Goldsmith Inlet and Goldsmith Pond were calculated with the DYNLET model. DYNLET is a 1-D plus model in that it solves for current velocity at specified stations along each cross section. Water level at the nodes and velocity at the stations are calculated, with the velocity apportioned at the stations according to the bottom friction or conveyance of the channel. A uniform rectilinear bathymetry grid for Goldsmith Inlet and Goldsmith Pond was created by importing the Oct 2002 bathymetry survey data into DYNLET. Thirty-one nodes with cross sections of varying length were then generated (Fig. 6).

The model was forced at Node 1 with water level measurements adapted from the Mattituck Inlet jetty gauge, and a no-discharge boundary condition (current velocity of zero) was specified at Node 31 located at the back of the pond. The distance between nodes was determined so as to represent significant changes in morphology through consideration of channel or pond width, depth, and roughness of the bottom. The DYNLET grid of Goldsmith Inlet originates approximately 200 m offshore. The distance between nodes within the channel and pond is approximately 20 m.

Water level measurements obtained offshore of Mattituck Inlet from 19 Sep to 8 Oct 2002 drove the model. The relation between MSL and NAVD88 at Goldsmith Inlet and Pond is not known. It was found by numerical experimentation that raising the water surface elevation by 0.25 m produced a successful model simulation that accurately represented the tidal signature recorded at Goldsmith Pond, while not drying the channel.

The authors have never observed the inlet channel to dry, even during low tide. A shift upward in the driving water level is functionally equivalent to shifting the entire bathymetry grid down by the same amount.

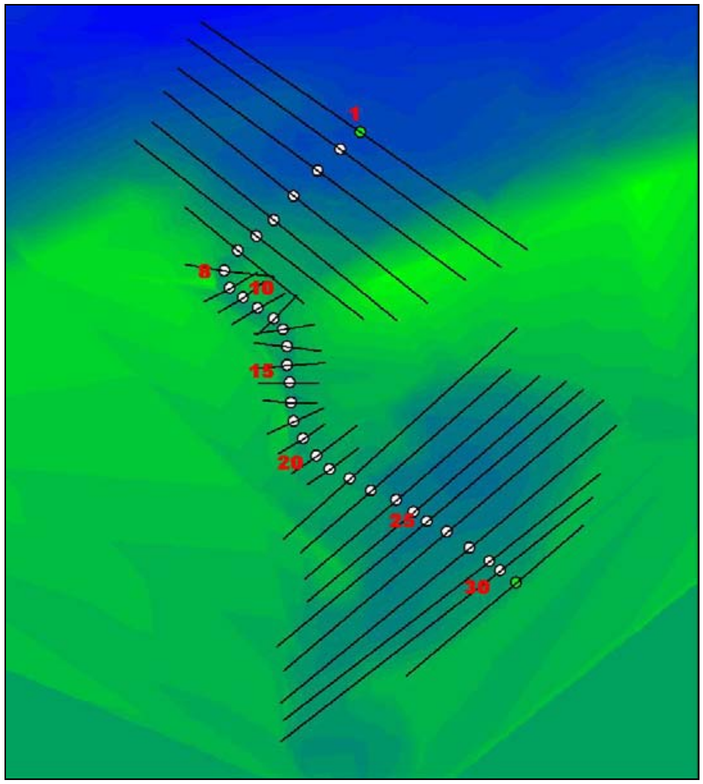

Fig. 6. DYNLET grid of Goldsmith Inlet, with nodes and extents of nodal cross-sections

DYNLET was calibrated by specifying larger values of the bottom friction coefficient in the Goldsmith Inlet channel, where small rocks are present and can protrude above the water surface, some of which may be remnants from jetty construction. The default value of Mannings *n* of 0.025 m/sec$^{1/3}$ was maintained at most nodes, but in the channel where rocks and roiling water are observed, the value was increased to 0.03 to 0.04. The time step in the model was set as 30 sec. The tidal record offshore of Mattituck Inlet was therefore adjusted forward 36 min to account for the time of tidal wave travel. This adjustment implies that the tidal wave moves westward at about 0.23 m/sec along the shallow water of this portion of the north shore of Long Island.

Figure 7 compares measured and calculated water level for 5-8 Oct 2002, a period of spring tide. Current velocity measurements taken for a short interval on 8 Oct 2002 are compared to corresponding DYNLET current velocity calculations (Nodes 13 and 14) in Fig. 8. The calculations well reproduce the limited length of the measurements. The current velocity is strong, exceeding 1 m/sec, and the calculated current is flood dominant.

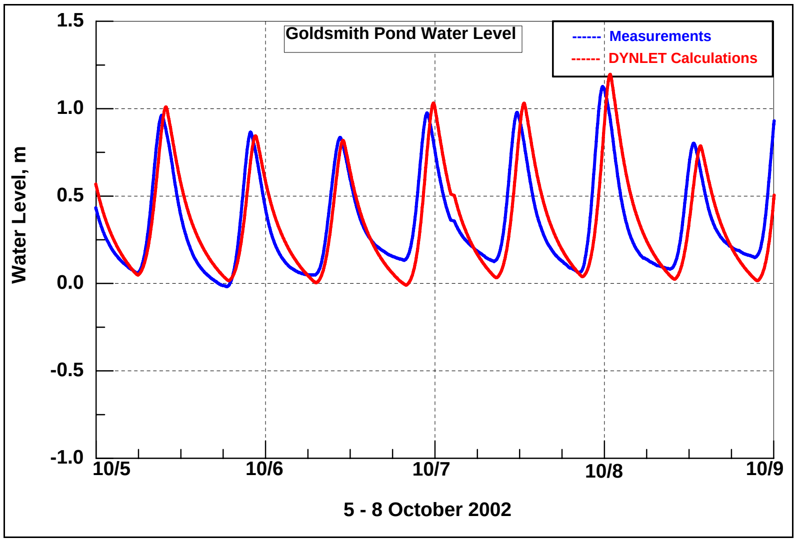

Fig. 7. Water level measurement and calculations (Node 30) off shore of Goldsmith Inlet 5-8 Oct 2002

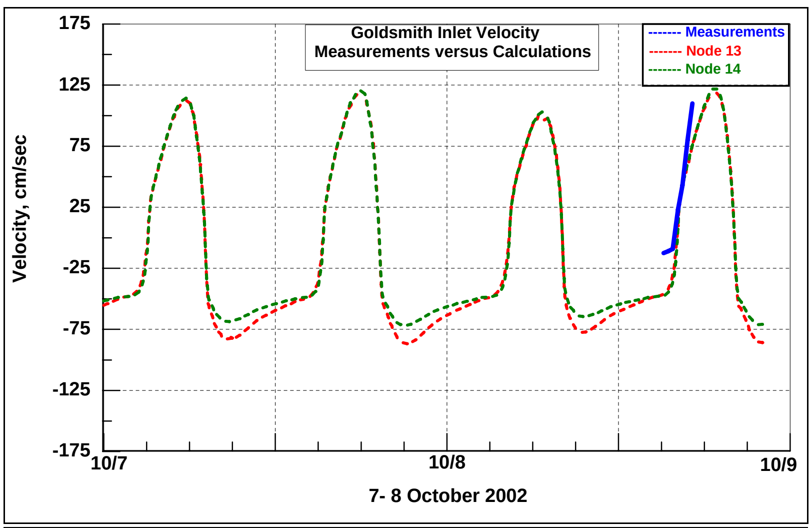

Fig. 8. Measured and calculated current velocity at Nodes 13 and 14, 7-8 Oct 2002

MORPHOLOGY CHANGE AND CHANNEL MIGRATION

Our analysis indicates that the greatest rates of erosion on the down-drift beach occurred between 1972 and 1978. Effective natural sediment bypassing was not established until the spit directly east of the jetty had reached a certain volume and areal extent. The impoundment fillet directly west of the jetty was the apparent primary sediment sink in this area prior to 1972. After this, the formation of the spit directly east of the jetty became the primary sediment sink for the local sand-sharing system. This period may have also been characterized by greater rates of sediment intrusion within the inlet.

Construction of the jetty apparently stabilized the inlet for 17 years by blocking eastward-moving material, because the first dredging of record occurred in 1977.

Goldsmith Inlet was dredged seven times until 1990, and several times in the early 1990s. The inlet apparently maintained a degree of stability from the mid 1990s to 2002. The relatively large tidal range and large sediment grain size contribute to inlet stability. The instability observed in recent times may owe to continued degradation of the jetty, which allows sediment to enter the inlet.

Because Goldsmith Inlet is free to migrate to the east and away from the jetty, the location of its entrance channel is dynamic. The orientation of the channel, sediment impoundment west of the jetty, and the formation of a fillet east of the jetty were analyzed for times available from aerial photographs. The reorientation indicates that the inlet is presently an ephemeral inlet, in contrast to the preceding century when it was apparently more stable and open.

Figure 9 shows selected orientations of the inlet entrance from 1993 to 2004. Change in location and morphology of the Goldsmith Inlet channel entrance between 6-8 Oct 2002 and 16 Apr 2003 is substantial. Sediment accumulation extended the beach 18-25 m for the 150 m directly east of the jetty, and the entrance channel mouth migrated 107 m to the east. The effective greater length of the channel reduces the ebb flow and contributes to closure. The acute angle of the inlet relative to the shoreline however allows for more effective sediment bypassing.

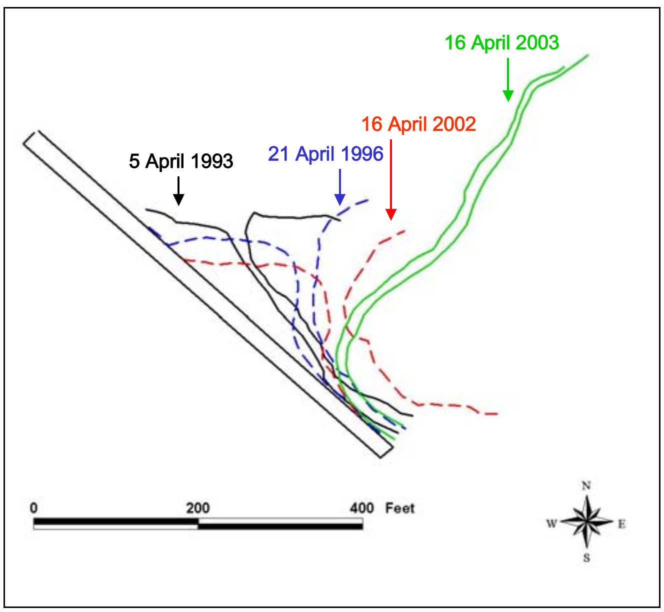

Fig. 9. Goldsmith Inlet channel entrance orientation, 1993-2003

TIDAL ASYMMETRY

The times series of water level in Goldsmith Pond exhibits three remarkable properties: (1) low tide usually does not reach 0 NAVD88, which is approximately MSL at the site, (2) the tide range in the pond is less than half that in Long Island Sound, and (3) water level rises much more rapidly than it falls, and the duration of ebb is much longer than flood. Properties (1) and (2) are related. In Goldsmith Pond, the duration of the average ebb tide (peak to trough) of record was 8 hr, 56 min, and the duration of the average flood tide (trough to peak) was 3 hr, 28 min.

Tidal asymmetry of coastal inlets has been well studied and is summarized by Walton (2002). For example, shoaling channels truncate the lowest portion of the tide, resulting in a longer falling tide and weaker ebb current as compared to the flood current. Such a truncation is a hypsometric effect, the control of water surface elevation by the geometry of the bathymetry or depths. At the inlet, the elevation of the entrance is near MSL. At the lower water levels of ebb tide, the sills at the flood shoal and shoreline become more effective in retarding flow. In addition, water enters the fringing marsh of Goldsmith Pond on flood tide more rapidly than when it exits on ebb. The effective friction of the marsh, creating storage capacity, will release water slowly as compared to its entrance at flood tide.

The tidal water levels calculated in DYNLET levels exhibit strong asymmetric behavior for Goldsmith Inlet. Figure 10 plots water level at selected nodes along the inlet channel for 5-8 Oct 2002. At nodes located near the forcing in Long Island Sound, the water level signal is sinusoidal. With distance into the inlet, the water level signal becomes more asymmetric, achieving a greater maximum on flood than on ebb, and with a shorter time of flood than ebb. There are three possible causes for the asymmetry. The first and likely dominant cause is the presence of sills in the inlet. The higher water of flood can enter the inlet rapidly, because the tide wave celerity is given by the square root of the product of gravitational acceleration and depth. On the lower water of ebb, the depth has decreased, and the water that can ebb slows. Connected with this hypsometric change in wave speed, bottom friction will retard flow more strongly for shallower water.

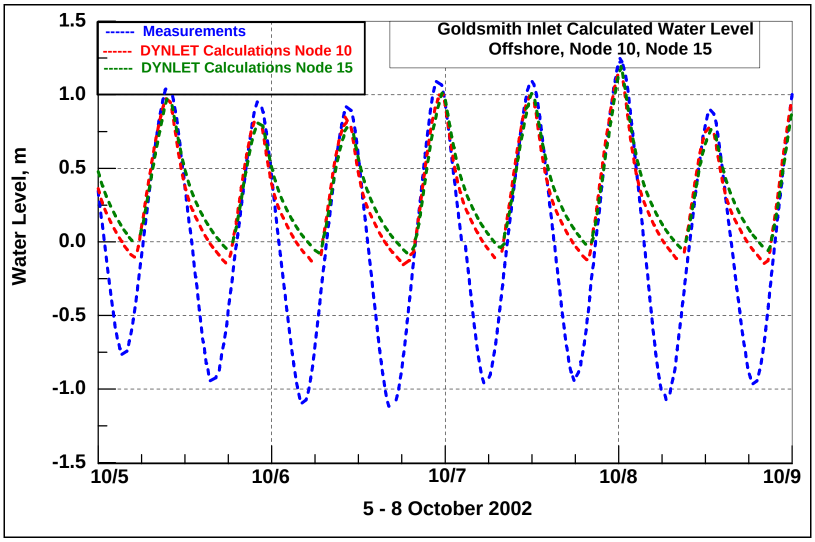

Fig. 10. Water level measurements offshore of Goldsmith Inlet and DYNLET Nodes 15 and 20 calculations, 5-8 October 2002

A second cause for the asymmetry in water level and current signals in the inlet and pond is the preferential drainage in the wetland surrounding Goldsmith Pond. It is expected that flooding water will enter the wetland more rapidly than the draining water on ebb.

A third reason for the asymmetry is the non-linear interactions of flow components introduced by the bottom friction terms and advective terms in the equations of motion.

Figure 11 plots the maximum calculated velocity at each node for a spring flood tide and the subsequent ebb tide on 7 Oct 2002, together with the bottom elevation. The flood current had maximum velocity of 1.43 m/sec for this time interval. Strong flood-tidal currents persist to the exit of the channel into Goldsmith Pond. The ebb current at the mouth exceeds 1 m/sec.

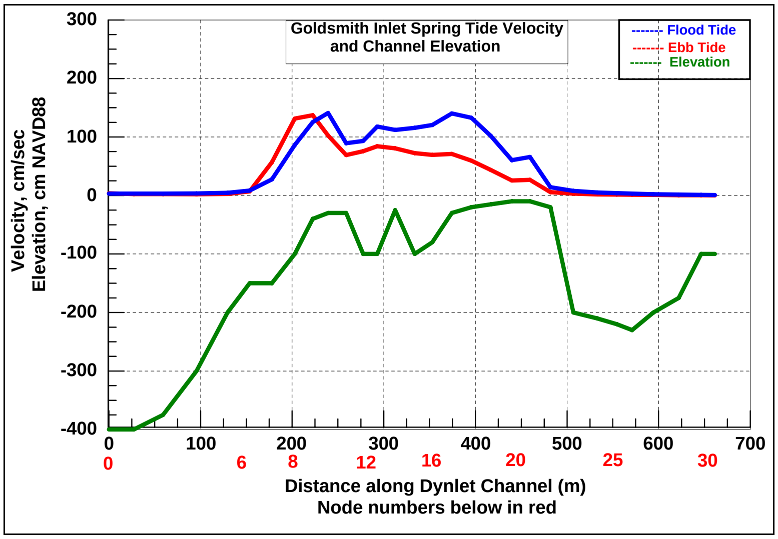

Fig. 11. Maximum calculated flood and ebb spring tide current speed and water elevation 7 Oct 2002

Figures12 and 13 display composite surfaces of maximum calculated flood and ebb velocity within the channel for hours 400 to 450 of the model run. A strong flood current persists over the entire channel and into the pond, whereas the ebb current is weak over much of the channel and pond, except at the mouth of the inlet. Such behavior would tend to transport sediment, particular sand, toward Goldsmith Pond, promoting flood shoal development and growth. The strong ebb current at the entrance would tend to maintain the inlet by sweeping finer sediments away from the mouth. However, sediment brought into the inlet on flood will not be flushed on ebb, promoting closure by constriction inside the inlet and not necessarily at the mouth.

CONCLUDING DISCUSSION

The presence of a tidal mill at Goldsmith Inlet in the 18th and 19th centuries indicates stability of the channel and strong tidal flow prior to the partial modifications of 1963-1964. The construction of the west jetty and the new-work dredging (1964) promoted stability of the inlet by substantially interrupting longshore transport of sediment to the east for approximately 14 years. In 1978, the jetty at Goldsmith Inlet appears to have reached impoundment capacity. Thereafter, sediment intrusion into the Inlet increased, promoting dynamic morphological evolution within Goldsmith Inlet, partially mitigated by dredging. The increased rates of sediment intrusion resulted in the creation of an attachment fillet directly east of the inlet, the eventual maturation of the flood shoal, and a subsequent increase in the rate of channel infilling.

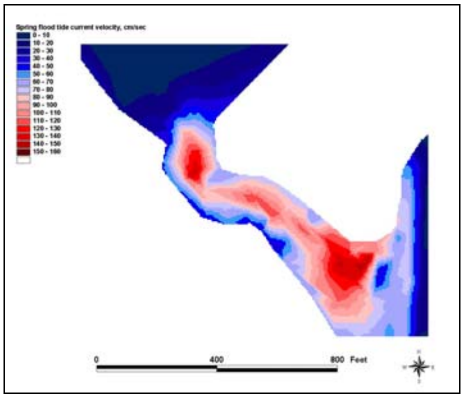

Fig. 12. Goldsmith Inlet spring flood tide maximum current velocity, inlet channel

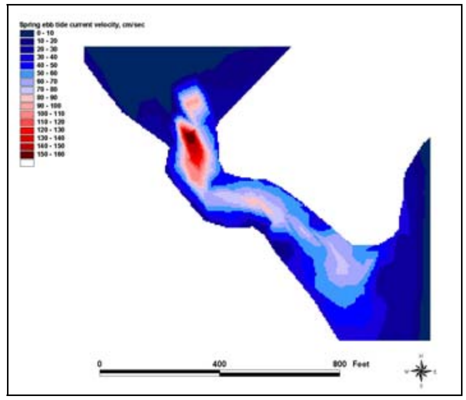

Fig. 13. Goldsmith Inlet spring ebb tide maximum current velocity, inlet channel

Re-establishment of an effective natural longshore sediment bypassing system appears to have taken place sometime in the early 1980s, when an attached fillet located directly east of the jetty reached an areal extent that promotes bypassing. Partial dredging from 1980 to 2000 apparently mitigated the continued growth and maturation of this attached fillet, and the eastward migration of the inlet entrance. The lack of dredging in recent years (in addition to continued degradation of the jetty) has allowed for rapid growth of this feature and resulting eastward migration of the inlet entrance (2001-2002). Re-establishment of a natural system of sediment bypassing has occurred, where sediment is transferred from this attached fillet via a bypassing bar located near the swash zone and eventually to the beach east of Goldsmith Inlet.

The current through Goldsmith Inlet is strongly flood dominant, determined in main part by the shallow sills in the channel. Because sediment transport is proportional to a power of water velocity, net sediment transport is directed into Goldsmith Pond. The greater velocity magnitude at the inlet mouth entrains and transports larger grain sizes. As the current velocity magnitude decreases with distance into the inlet, gradational deposition occurs, with the larger grain size fractions deposited and finer sediments transported further into the inlet.

The elevation of the entrance to Goldsmith Inlet is located near MSL. At the lower water levels of ebb tide, the sills at the flood shoal and shore become more effective in retarding flow. In addition, water enters the fringing marsh of Goldsmith Pond on flood tide more rapidly than when it exits on ebb. The effective friction of the marsh, creating storage capacity, releases water slowly as compared to its entrance at flood tide.

The mouth of Goldsmith Inlet appears to be at or near locational and cross-sectional equilibrium if it is oriented to the east, as shown in Fig. 1. Past dredging practice has realigned the channel parallel to the jetty. It is concluded that an orientation with the mouth directed to the east is the optimum for sediment bypassing and maintenance of inlet stability. The accretion fillet to the east, between the jetty and the inlet mouth, now functions to bypass sediment via transport by wave-induced current in the swash zone and by the ebb current issuing from an easterly orientation. If the accretion fillet to the west were mined substantially, impoundment at the jetty would reduce the sediment bypassing volume, turning back the processes in time.

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